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Aerial survey of vertebrates in the Mann River district, central Arnhem Land

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Abstract

An aerial survey of large vertebrate fauna was undertaken in the Mann River district of central Arnhem Land in September 2000. The survey covered 3936 km^2 of the eastern and central part of the Arnhem Plateau and 1944 km^2 on the adjacent lowland. A total of 747 individual animals from eight species were observed during the survey. Of these, four species were native (antilopine wallaroo, black wallaroo, emu and euro) and four were feral (buffalo, cattle, horse and pig). The majority of sightings (92%) were of feral animals, of which 78% were buffalo. The distribution of feral animals was largely similar to that of previous surveys with a high concentration in the upper Mann River and McCaw Creek regions. Sightings of native species were scattered throughout the survey area. The uncorrected density estimates (km^{-2} ± SE) for species observed in this aerial survey were: buffalo 0.74 ± 0.08; cattle 0.10 ± 0.04; horse 0.009 ± 0.008; pig 0.007 ± 0.003; black wallaroo 0.02 ± 0.006; and emu 0.006 ± 0.003.

Introduction

Arnhem Land is a large area of Northern Australia that is owned and managed by Aboriginal people. Arnhem Land covers over 95,000 km^2 in the north-east of the Northern Territory and encompasses an array of habitats from coastal and inland water systems, to monsoon forest, open woodland and the escarpment of the Arnhem Plateau (Cole 1978). The area is home to a large number of feral animals such as buffalo (*Bubalus bubalis*), cattle (*Bos taurus*), horses (*Equus caballus*) and pigs (*Sus scrofa*) that were introduced to the Northern Territory in the late 1800's (Chaloupka 1982). While some feral animals are utilised as a food resource by Aboriginal communities (Altman 1987), they can also cause significant environmental damage and are a potential disease threat when densities are high (Bayliss and Yeomans 1989a). The continued monitoring of feral vertebrate populations in Arnhem Land is important to ensure that densities are maintained at appropriate levels.

Aerial surveys provide the means by which large vertebrate populations can be monitored over great area and in remote locations (Clancy 1999). The vertebrate fauna of central Arnhem Land has previously been surveyed by light aircraft on two occasions in the past two decades (Bayliss and Yeomans 1989a, Saalfeld 1998), and these surveys have shown significant but decreasing numbers of feral animals over a thirteen-year period.

This report provides information on the distribution, density and population size of feral animals (buffalo, pigs, horses, and cattle) in the northern section of the Arnhem Land plateau and adjacent lowland areas northwest of the plateau. The current survey was not intended to replicate previous broad-scale surveys, bur rather attempted to provide information on the range and distribution of emu (*Dromaeus novaehollandiae*) and macropod species. However, it became evident early in the survey that the technique was not precise enough for this purpose and the focus of the survey switched to feral animals, in particular feral buffalo. Nevertheless, some information for emu, black wallaroo *Macropus bernadus* and antilopine wallaroo *Macropus antilinopus* is included here.

Methods

Aerial survey

An aerial survey was carried out between 7-11th September 2000 in central Arnhem Land by members of the Key Centre for Tropical Wildlife Management (Tony Griffiths and Jennifer Koenig) and the Djelk Rangers (Charles Godjuwa, Otto Campion and Dean Yibarbuk). The survey was based at Margalwo outstation on the Arnhem Plateau (12° 50.1'S, 133° 55.1'E), approximately 100 km southeast of Maningrida township. The survey area (5880 km^2) is composed of two distinct habitat types, plateau (3936 km^2) and lowland (1944 km^2). The plateau is characterised by rugged sandstone outcrop with low open rocky woodland while the lowland is primarily floodplains and tall open forest on deep sandy soils.

The survey area was systematically sampled by east-west transects placed 2.8 km apart on the plateau and 3.7 km apart on the lowland survey (Fig. 1). A total of 39 transects, each 54 km long, were flown giving a sampling intensity of 18.5% (626 km^2) on the plateau and 12.2% (237 km^2) on the lowland survey. A Cessna 185 fitted with a radar altimeter and global positioning system was used for the survey. The aircraft was flown at an altitude of 200 ft (61 m) above ground level at a ground velocity of 100 knots (185 kmh^{-1}). The transect width of 200 m each side of the aircraft path was delineated using fibreglass rods attached to the wing struts. The transect width was calibrated by flying at 61 m over two forty-four gallon drums placed 200 m apart on the runway.

There were two observers (port and starboard) in the rear of the plane, while a third person (seated front starboard) acted as recorder. For a sub-sample of transects, the recorder acted as a third observer. The position and time of each observation was recorded using a Hewlett Packard HP200LX palmtop computer programmed as a datalogger and linked to a GPS. For each observation the following information was recorded: species; number of animals per group; habitat in which the group (or individual) was seen; and observer. Habitats were grouped into four broad categories: open woodland (moderate canopy cover and height); wet woodland (wetland and riparian habitats); rocky woodland (low and sparse canopy); and sandsheet forest (tall forest dominated by *Eucalyptus tetrodonta*).

Data analysis

Density and population estimates were calculated for each species using the ratio method (Caughley 1979). Correction factors were not calculated for this survey as double counts were only gathered for a small sub-sample of transects. However, we have included results based on the correction factors from a previous aerial survey of Arnhem Land (Bayliss and Yeomans 1989b). These factors correct for observer bias in the open woodland and are applied here to provide a more accurate approximation of the actual number of buffalo, cattle and horses present.

Students t-tests were used to compare the density of each species (with ten or more sightings) in plateau and lowland areas. Students t-tests were also used to compare animal sightings between the port and starboard side of the plane. A contingency table analysis was used to test whether species differed in the proportion of animals observed in each of the major habitat types. We also tested for difference in buffalo abundance across habitat types using a one-way ANOVA, using the raw group size data. For all buffalo sightings, we calculated the distance to the nearest drainage line using ArcView 3.2a.

Results

Distribution, density and population estimates

A total of 747 individual animals from 8 species were sighted during the aerial survey. Of the 8 species observed, 4 were native (emu, antilopine wallaroo, black wallaroo and euro) and 4 were exotic (buffalo, cattle, horse, pig). The sightings, number of individuals and mean group sizes for each species are presented in Table 1. The majority of sightings were for feral animals (92%), with buffalo accounting for 78% of sightings.

Figures 2 and 3 show the distribution of sightings for each species. Although buffalo were widely distributed throughout the survey area, most were concentrated on the

Table 1. Summary of sightings, individual counts and mean group size estimates (± one standard error) for wildlife species recorded during the aerial survey.

	Sightings	*Individuals*	*Mean group size*
Buffalo	185	623	3.4 ± 0.27
Cattle	24	88	3.7 ± 0.9
Horse	2	8	4 ± 3
Pig	6	6	1 ± 0
Antilopine Wallaroo	1	2	2
Black Wallaroo	12	14	1.2 ± 0.11
Emu	4	5	1.3 ± 0.25
Euro	1	1	1

eastern side of both the plateau and lowland survey blocks, and in particular around the McCaw Creek and Mann River regions in the southeast. Feral cattle had a more patchy distribution and horses were confined to the southeast of the survey. In contrast, sightings of the black wallaroo were concentrated in the northwest region of the plateau, west of Margalwo outstation. The small number of sightings of the other native and feral species were scattered throughout the survey area (Fig. 3).

The uncorrected density estimates for each species are presented in Table 2, calculated for the entire survey area and separately for the plateau and lowland. There were no significant differences in density between the plateau and lowland areas for buffalo ($t = 0.93$, $p = 0.35$), black wallaroos ($t = 0.89$, $p = 0.38$) or cattle ($t = 1.79$, $p = 0.082$).

The uncorrected population estimates calculated for each species sighted in the survey are presented in Table 3. Due to the low number of sightings the precision (measured by the SE) of the estimate is poor for all species except buffalo. Corrected estimates for buffalo, cattle and horses are presented in Table 4.

Habitat variables

Contingency table analysis showed that the proportion of animals in each major habitat type differed significantly between species ($c^2 = 85.41$, $p < 0.001$). These results reflect two distinct patterns, with feral animals (buffalo, cattle, horse and pig) sighted more often in the open and wet woodland and native species (black wallaroo and emu) more often in the rocky woodland (Table 5).

The size of each buffalo group was significantly related to the habitat in which the group was seen ($F = 2.93$, $p = 0.03$). The mean group size (± one standard error) of

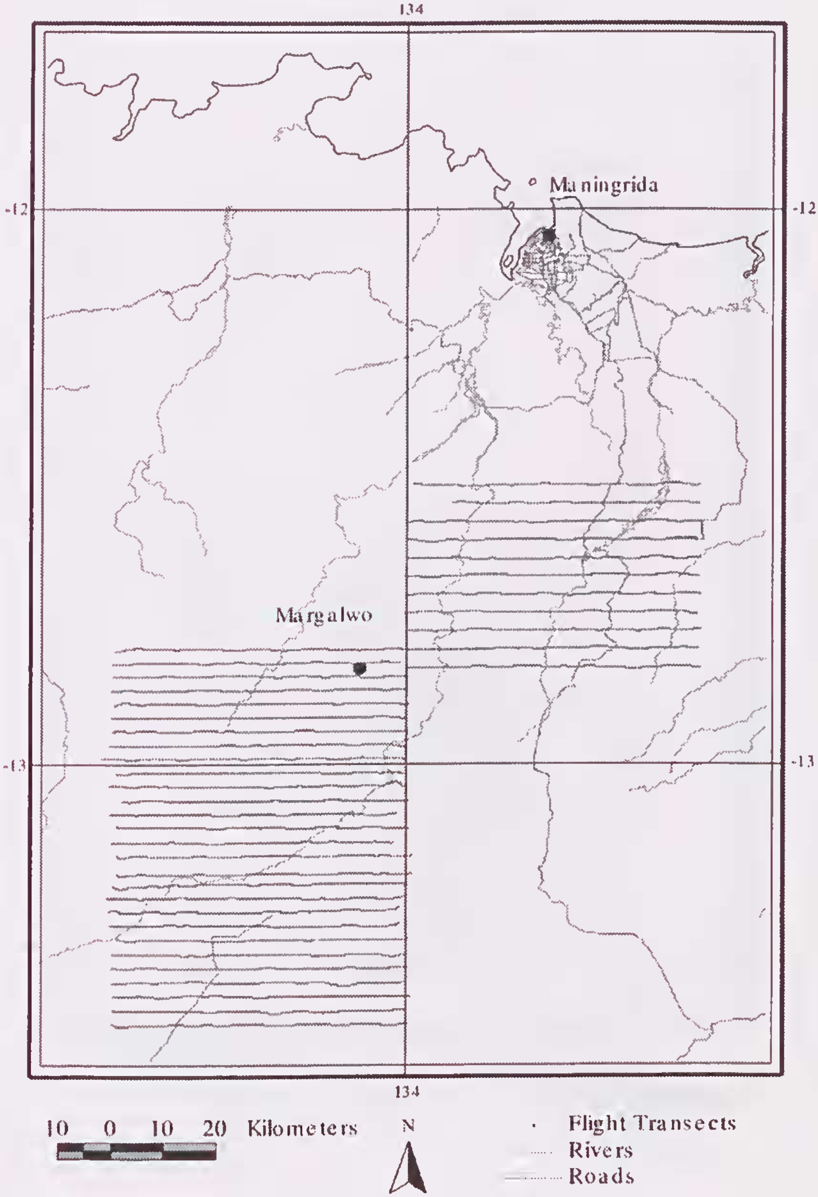

Figure 1. Location of aerial survey flight transects.

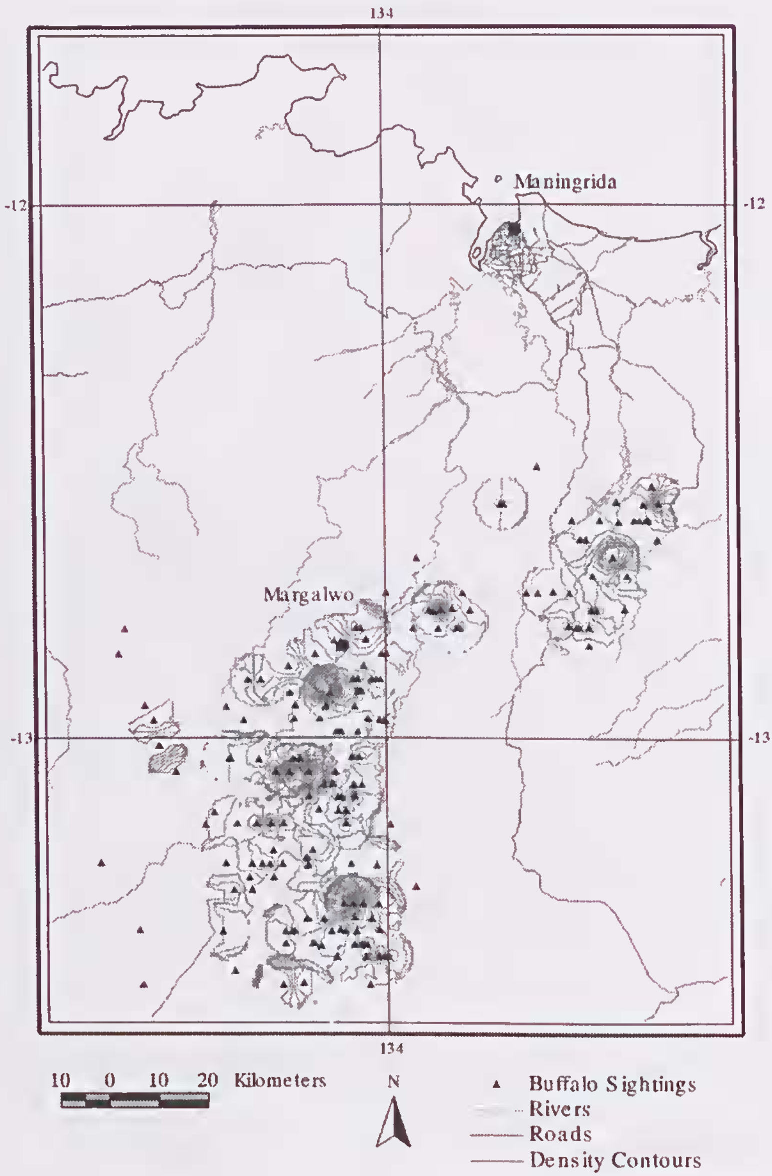

Figure 2. Distribution and density patterns of buffalo sighted in the aerial survey. Density contours have a base of 1 and an interval of 1.

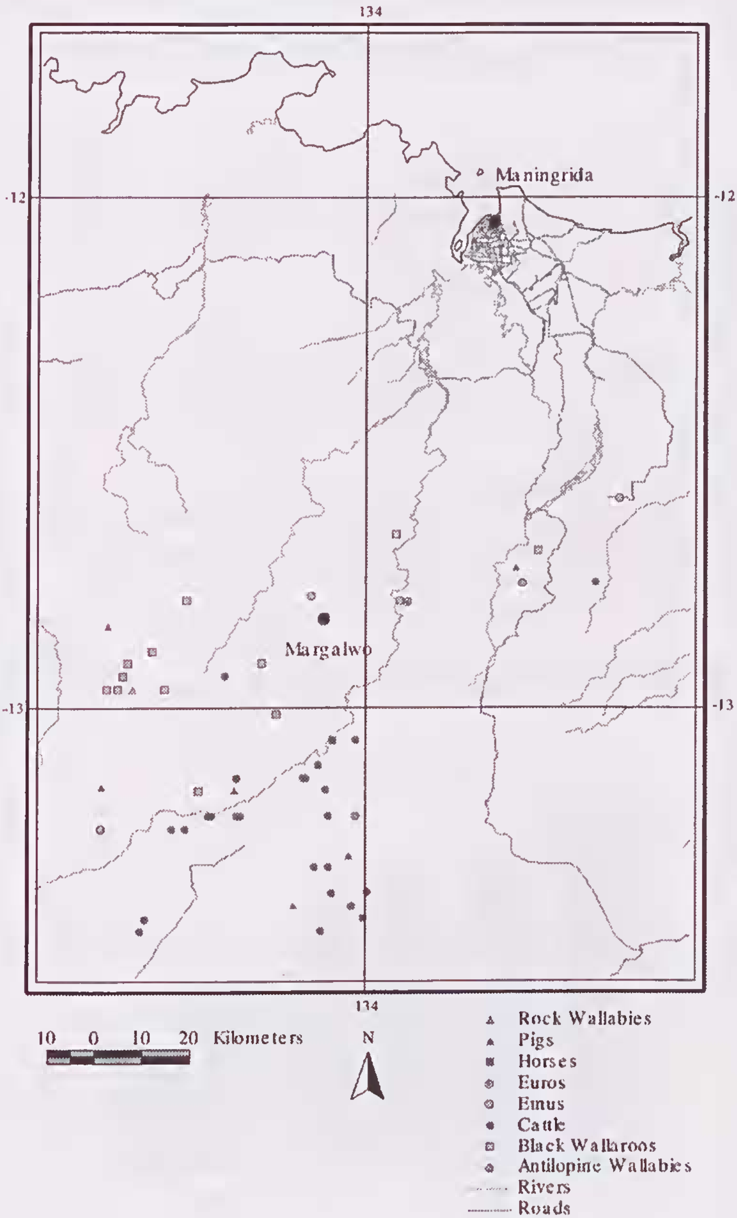

Figure 3. Distribution of all species (except buffalo) sighted in the aerial survey.

Table 2. Uncorrected density estimates (animals per km^2 ± one standard error) for wildlife species recorded during the aerial survey. Estimates were calculated for the entire survey area and separately for the two topographic regions (plateau and lowland).

	Total (5880 km2)	*Plateau (3936 km2)*	*Lowland (1944 km2)*
Buffalo	0.74 ± 0.08	0.79 ± 0.09	0.61 ± 0.18
Cattle	0.10 ± 0.04	0.14 ± 0.05	0.004 ± 0.004
Horse	0.009 ± 0.008	0.013 ± 0.011	0
Pig	0.007 ± 0.003	0.008 ± 0.004	0.004 ± 0.004
Black Wallaroo	0.02 ± 0.006	0.02 ± 0.008	0.008 ± 0.006
Emu	0.006 ± 0.003	0.002 ± 0.002	0.02 ± 0.009

Table 3. Uncorrected population estimates (± one standard error) of wildlife species recorded during the aerial survey, September, 2000. Estimates were calculated for the entire survey area and separately for the two topographic regions. Values in parentheses are the standard error as a proportion of the estimate.

	Total (5880 km2)	*Plateau (3936 km2)*	*Lowland (1944 km2)*
Buffalo	4349 ± 492 (0.11)	3105 ± 366 (0.12)	1195 ± 352 (0.29)
Cattle	614 ± 213 (0.35)	566 ± 191 (0.34)	8 ± 8 (1)
Horse	56 ± 49 (0.88)	52 ± 46 (0.88)	0
Pig	42 ± 19 (0.45)	33 ± 16 (0.48)	8 ± 8 (1)
Black Wallaroo	98 ± 34 (0.35)	78 ± 30 (0.38)	16 ± 11 (0.69)

Table 4. Corrected density and population estimates (± one standard error) of buffalo, cattle and horse observed during the aerial survey. The correction factors are those of Bayliss and Yeomans (1989b) for the open woodland habitat.

	Total (5880 km2)	*Plateau (3936 km2)*	*Lowland (1944 km2)*
Buffalo	4349 ± 492 (0.11)	3105 ± 366 (0.12)	1195 ± 352 (0.29)
Cattle	614 ± 213 (0.35)	566 ± 191 (0.34)	8 ± 8 (1)
Horse	56 ± 49 (0.88)	52 ± 46 (0.88)	0
Pig	42 ± 19 (0.45)	33 ± 16 (0.48)	8 ± 8 (1)
Black Wallaroo	98 ± 34 (0.35)	78 ± 30 (0.38)	16 ± 11 (0.69)

buffalo in open woodland, wet woodland, sand-sheet forest and rocky woodland was respectively: 3.13 ± 0.49; 4.43 ± 0.51; 2.54 ± 0.37 and 2.37 ± 0.60. Over 80% of all buffalo sightings were within 400 m of a drainage line (Fig. 4).

Observer bias

The mean number of animal groups sighted per transect was 3.72 for the starboard side of the plane compared to 2.08 for the port side ($t = 2.87$, $p = 0.005$). Similarly, the mean number of individual animals counted per transect was significantly higher on the starboard side (10.72 *vs* 5.54: $t = 3.08$, $p = 0.003$). The observers on the port

Table 5. The number of sightings for each species in each of the four habitat types, as a percentage of the total number of sightings (in parentheses) .

	Open woodland	*Wet woodland*	*Sandsheet forest*	*Rocky woodland*
Buffalo (185)	38	33	19	10
Cattle (24)	70	17	4	9
Pig (6)	33	50	0	17
Black Wallaroo (12)	0	0	8	92
Emu (4)	0	0	25	75

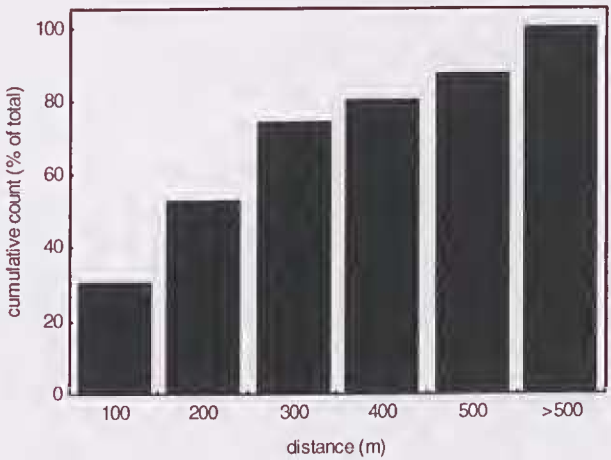

Figure 4. Distance of buffalo sightings to the nearest drainage line.

and starboard side of the plane remained consistent for 31 out of the 39 transects. Analyses of the most commonly sighted species (buffalo) for these 31 transects revealed a similar pattern to that described above for all animal sightings.

Discussion

Distribution, density and population estimates

Feral buffalo were widespread throughout the entire survey area (Fig. 2) with particularly high concentrations around the McCaw Creek and Mann River region in the east of the plateau survey area. In contrast, feral horses, pigs and cattle were patchily distributed, with concentrations in the Bulman Gorge and upper Mann River area at the southern end of the survey area (Fig. 3). This area has been identified in previous aerial surveys as having a relatively high density of feral animals (Saalfeld 1998, Bayliss and Yeomans 1989a).

The uncorrected buffalo density estimates from this study are higher than those reported in the last extensive aerial survey of Arnhem Land in 1998 (Saalfeld 1998). However, buffalo density from the 1998 survey for the same area was 0.85 km^{-2} (K. Saalfield, pers. comm.). This suggests a relatively stable buffalo numbers over the two years between these surveys. Buffalo densities reported for this area from an aerial survey in 1985 (Bayliss and Yeomans 1989a) were higher than the results from the present survey. The apparent decrease in buffalo numbers over the 15 year period may be due to the BTEC (Brucellosis and Tuberculosis Eradication Control) program, which operated in Arnhem Land between 1985 and 1995 (Ridpath and Waithman 1988, Saalfeld 1998). Alternatively, mustering may have reduced numbers, particularly in the southern part of the survey area. The density estimates for feral cattle are also similar to those reported by the 1998 Arnhem Land feral animal survey (Saalfeld 1998). In contrast, density estimates for horse are much lower in the present survey, but our survey did not encompass the areas of high horse density sampled by Saalfield (1998).

A factor that may influence the results of aerial survey is the choice of sampling platform. There are particular advantages and disadvantages associated with each sampling platform (helicopter versus fixed-wing aircraft) and these will determine the method used in a particular survey. A helicopter is able to travel slower and at lower heights than a fixed-wing aircraft allowing for easier species observation and identification (Clancy 1999). However, the cost of a helicopter survey is considerably greater, the duration of each flight shorter and consequently the survey area is much smaller than if using a fixed-wing aircraft (Clancy 1999). For this survey we used a fixed wing aircraft in order to cover a large area of central Arnhem Land. While the use of this sampling platform enabled us to effectively sample the larger vertebrates (buffalo and cattle) it compromised our ability to detect the smaller native animals. A recent helicopter survey of a small section of Arnhem Land (covering part of the lowland area sampled in this survey) recorded a much higher density of large macropods (9.3 km^{-2}) and emu (0.3 km^{-2}; Yibarbuk *et al.* 2001) than was detected with the present fixed-wing aircraft survey.

Estimates of density and population from aerial surveys are negatively biased and represent only a proportion of the actual population (Bayliss and Yeomans 1989b). The use of correction factors is a method of accounting for this negative bias (Cairns 1999). Ideally, survey specific correction factors should be obtained by using a combination of the double count methodology (Marsh and Sinclair 1989; Bayliss and Yeomans 1989b) and ground survey techniques. The correction factors of Bayliss and Yeomans (1989b) used in this report are a combination of both observer and environmental bias and should be used with caution when applied to other surveys. Thus, while the corrected density and population estimates for buffalo, horses and cattle (Table 4) provide a more accurate approximation than the uncorrected values, they are unlikely to be entirely accurate.

Habitat variables

We found that the mean group size for buffalo was significantly different between the major habitat types. Previous surveys have demonstrated a negative relationship between visibility of buffalo and canopy cover, and have derived correction factors for each habitat based on mean group size (Bayliss and Yeomans 1989b). Thus, our results may reflect a group visibility bias in relation to habitat type. Alternatively, some habitats may be more favourable to buffalo and support larger group sizes. The presence of water seems to be one factor influencing the distribution of buffalo, with over 80% of all buffalo sighted within 400 m of a drainage line. Similarly, previous surveys have noted that wetland and *Eucalyptus* woodland endowed with fresh water (rivers, creeks, springs and billabongs) were areas of high buffalo density (Bayliss and Yeomans 1989a).

Observer bias

This survey served, in part, as an educational exercise in aerial survey techniques for members of the Key Centre for Tropical Wildlife Management and the Djelk Aboriginal Rangers. The participants of this aerial survey had minimal experience in observing and counting animals from the air. It is recommended that observers have a minimum air training time of 100 hours before being included in the collection of data (Bayliss and Yeomans 1989a; Beard 1999). The reasons for training include learning to work and concentrate in a confined and stuffy space for long periods; learning to work in turbulent conditions without feeling ill, and the need to develop a search image for each species form the air (Beard 1999). The use of inexperienced observers in this survey undoubtedly accounted for some inaccuracies in the data.

Recommendations and conclusions

The original aim of this study was to survey for emu and macropods. However, we were not able to accurately detect these species from a fixed-wing aircraft. For future surveys a helicopter may be a better alternative as they provide greater visibility and accuracy when surveying native animals (Clancy 1999; Pople *et al.* 1998). In order to obtain more accurate aerial survey data and to decrease habitat and observer bias we also recommend incorporating double-count techniques, habitat specific correction factors and ground-truthing into future aerial surveys (Bayliss and Yeomans 1989b; Clancy *et al.* 1997).

The feral animals in Arnhem Land are a valued resource to the Aboriginal owners. Large feral animals such as buffalo, cattle and pig provide an important food resource (Altman 1982, Altman 1987, Vardon *et al.* 1996), and commercial income is obtained from buffalo through "safari" tourism and periodic mustering (Johnson 2000). However, feral animals can cause significant environmental damage and are a potential disease threat (Bayliss and Yeomans 1989a, Ridpath and Waithman 1988). In order to manage feral animal populations to the benefit of local landowners, the distribution and density of feral species needs to be closely monitored. The use of aerial surveys provides the cost effective means of achieving this goal.

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